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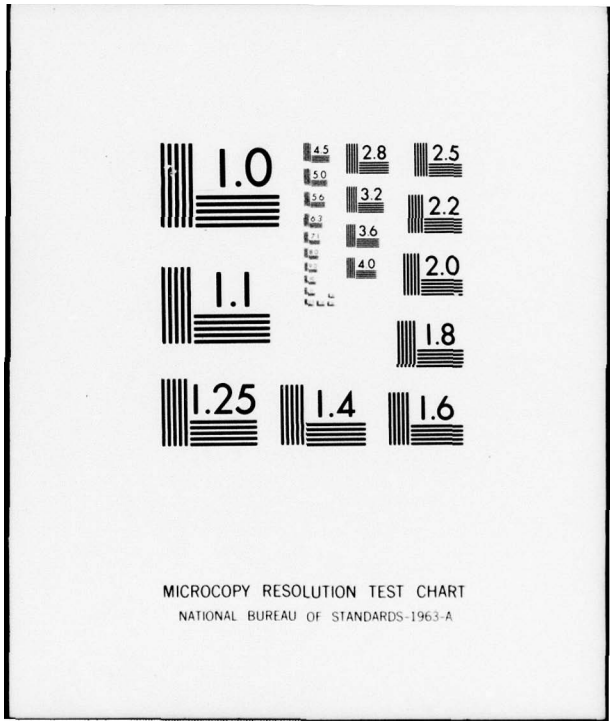
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AN EVALUATION OF THE GNP DEFLATOR AS A BASIS FOR ADJUSTING THE ALLOWABLE PRICE OF CRUDE OIL

CENTER FOR NAVAL ANALYSES
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The price controls on crude oil, beginning in February 1976, allowed the average price to grow at the same rate as the GNP deflator. An additional increase up to 3% per year was also allowed. Furthermore, the two adjustments to price were limited to a total of 10% per year.

The use of the GNP deflator to adjust the price of crude oil is evaluated to determine whether it compensates for changes in the prices of purchased items and labor used in the discovery and production of crude oil. A price index for these costs is

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cont → 20 constructed and compared with the GNP deflator for the period 1965 to 1976.

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EXECUTIVE SUMMARY

The Energy Policy and Conservation Act of 1975 established controls on the average price of domestic crude oil, effective February 1976. The controls were scheduled to remain in effect for at least 39 months after February 1976. Starting at $7.66 per barrel, the average price was allowed to rise as inflation progressed. The inflation adjustment was equal to the growth in the GNP deflator, up to a limit of 7% per year. An additional adjustment of up to 3%, to provide a production incentive, was also allowed.

In August 1976, the division between the inflation and incentive adjustments was temporarily suspended and a flat 10% increase allowed. In actuality, the price charged by individual sellers has been frozen since July 1976, since the average price of domestic crude oil exceeded the allowable price for some months after February 1976. As of March 1977, the inflation adjustment using the GNP deflator is scheduled to be reinstated.

It is clear that holding the price of crude oil constant while input prices are rising would erode incentives to explore for and produce oil. It seems reasonable to infer that the purpose of indexing the price of oil by the deflator is to maintain incentives as they were when price controls were first imposed. The deflator would serve this purpose well only if changes in cost are matched by changes in the deflator.

This paper evaluates the use of the GNP deflator to index the allowable price as an inflation adjustment. To do this, an index of the cost of inputs into exploration and production was constructed and compared to the GNP deflator. The cost index was estimated in several forms using varying assumptions and sets of data. Each form of the cost index was calculated from 1965 to the most recent period available in the data.

Before 1970, each form of the cost index showed at least a modest tendency to grow more rapidly than the GNP deflator. Some forms grew much more rapidly. All forms of the cost index grew more rapidly than the GNP deflator after 1970; the average growth rate of each form of the index exceeded the growth rate of the GNP deflator by at least 2.5 percentage points annually.

The tendency of the deflator to grow less rapidly than an index of costs can be explained by the deflator's method of construction. The deflator is an average of a number of different price indices. While it may be a good measure of inflation for the economy as a whole, it may well under-represent inflation in specific sectors. Moreover, it measures only the price level for final goods, excluding the price of most inputs. Though the prices of final goods tend to follow input prices, there are other important influences, such as increases in productivity, which lead the deflator to underestimate increases in input prices.

Our study should not be interpreted as a comment on the existence of price controls. It is instead a discussion of a particular adjustment to the controls. Moreover, we do not claim that adjusting perfectly for inflation would result in maintaining incentives. There are other sources of cost changes not covered by this adjustment. In addition, there are features of the controls that can prevent the increase of any producer's price even while the average price, as calculated under the 1975 law, is increasing. Indeed, we estimated that between February 1976 and November 1976, the change in the mix of upper- and lower-tier oil would have been sufficient to cause the average price, as calculated in the law, to increase by 5%, even if no producer increased his price during this period.

INTRODUCTION

The Energy Policy and Conservation Act (EPCA), passed in December 1975, set controls on the average price of crude oil produced in the United States at $7.66 per barrel as of February 1976. The EPCA stipulated that this average price could rise by the amount of inflation as measured by growth in the implicit price deflator for Gross National Product.* In addition to the inflation adjustment, a separate price increase of up to 3% per year was allowed to provide incentives for exploration and production.

The sum of the inflation and incentive adjustments was limited to 10% per year. Thus, the inflation adjustment was effectively limited to 7% whenever the incentive adjustment was at its maximum 3%. After March 15, 1977, the Federal Energy Administration can recommend a price increase exceeding 10%, but implementation is subject to Congressional approval.

The 1975 act was supplemented in August 1976 by the Energy Conservation and Production Act (ECPA). This act removed controls on oil from stripper wells, but left in effect the price controls on other oil.

The February 1976 price established a level of incentives for exploration and production. It appears that the inflation adjustment was included in the EPCA to bolster incentives; adjusting prices for inflation implies an intent to prevent erosion of the real returns, which determines incentives for exploration and production.

THE GOAL OF THIS STUDY

This paper examines the use of the GNP deflator as a basis for indexing the controlled price of oil. We focus on the costs of resources used in the discovery of new oil, and consider whether use of the deflator raises price enough to hold the percentage rate of return constant. The question we address is whether the inflation adjustment results in the controlled price rising at the same rate as do costs. If input costs grow faster than the change in allowable price, the incentive to supply the market will gradually fall; if costs grow slower than the change in allowable price, the incentive to find new oil will gradually increase.

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*This adjustment for inflation was in effect until August 1976, and is scheduled to be reinstituted in March 1977. In the interim, the maximum allowable price is allowed to rise at an annual rate of 10%. Because the average price of domestic crude oil exceeded the allowable level for some months after February 1976, the price actually charged by individual sellers has been frozen since July 1976.

Undoubtedly, some investments in oil exploration would occur at a price even lower than the price set in February 1976. However, there are also some investments in exploration which barely cover cost when the oil is sold at the controlled price. It is common to call such a barely profitable investment the "marginal unit" of investment. The relation between changes in the cost of the marginal unit and changes in price will determine whether total investment will rise or fall. If changes in the price of oil exactly match changes in cost, and all other factors remain unchanged, there is no a priori reason to anticipate either a rise or fall in investment.

Limits on the Scope of the Study

The scope of our study is limited in several ways. First, we consider only the basis for adjusting the controlled price; we are not concerned with what would have happened had prices not been controlled. Second, though we discuss the movement in the controlled price required to match cost changes, we do not discuss what would happen if the controlled price diverged from this path. Third, we discuss only one source of change in incentives: change in the cost of crude petroleum inputs. Several other sources of change, not related to the inflation adjustment, can also have important effects. Since we do not deal with them in the index, we discuss them more fully below before moving on to the methodology of the study.

One important source of change that is ignored here is the change in cost due to factor productivity. The reason for this exclusion goes back to the fact that separate adjustments are made for inflation and for production incentives. It is our interpretation that the latter is meant to adjust for changes in factor productivity. Since our project concentrates on the inflation adjustment, we do not evaluate whether the incentive adjustment adequately compensates for changes in factor productivity.

Because we ignore productivity changes, any inflation adjustment we recommend will be an incomplete estimate of the total adjustment required in the allowable price. If factor productivity in finding new oil changes as the search for new oil moves to new areas, an additional adjustment to the allowable price would be necessary to maintain incentives.

Another source of change that we ignore by concentrating on only the inflation adjustment is in the arithmetic of the allowable price formula. The 1976 price controls are not imposed directly on upper- and lower-tier oil, but on a weighted average of the two. As time passes, the ratio of lower-tier to upper-tier oil will fall. Even if the prices for each type remain unchanged, the weighted average price will rise. If the average allowable price is held constant, however, the price of one or both of the two types of oil will need to fall.

An example may clarify how changing the mix of upper- and lower-tier oil would affect the allowable price. In February 1976, the average cost of lower-tier oil was about $5.05 and the average price of upper-tier oil was about $11.47 . At that time, 56% of the oil produced domestically was classified as lower-tier and 44% was upper-tier. By November 1976, the share of lower-tier oil decreased to about 50%. Even if the prices that producers received had remained unchanged throughout the year, the average price of oil would have risen by 5%, from $7.87 to $8.26 . Thus, without compensating for inflation, the average allowable price would have had to rise by 5%, just to hold constant actual prices received by producers.

A final determinant of incentives not discussed in this paper is the price of natural gas. Since natural gas and crude oil are often found together, increases in the price of gas and crude oil are partial substitutes. The higher the price of natural gas, the lower the price of crude oil necessary to provide a given incentive.

To summarize, inflation is only one of the factors that can influence incentives. Other major influences arise from productivity changes, changes in the mix of upper- and lower-tier oil, and changes in the price of natural gas. This study examines only the effect of inflation.

AN OVERVIEW OF METHODS

As mentioned above, our main goal in this paper is to evaluate the GNP deflator as an index of inflation in petroleum input prices. To do this, we compare the deflator to an index of petroleum costs. The index of costs is based on the concept of the marginal unit of investment, the last unit of investment profitable to undertake at the February 1976 price. This marginal unit of investment is used to purchase a particular bundle of inputs for discovering crude oil, and to produce it once found.

We construct the index of crude oil input costs by identifying this bundle as closely as possible, and repricing it as inflation persists. The cost of the bundle is expressed as an index which is the cost of the bundle in each period divided by its value in some base period. We refer to the index constructed in this way simply as a cost index, though as noted above, we intentionally exclude some elements of cost.

In identifying the bundle of inputs to include in the index, it would be ideal to use those that are actually required in the marginal unit of investment. Since such data are not available in published statistics, we use the best available alternative, average input quantities for the industry as a whole.

The cost index we derive is computed in several different forms, using differing sources of data and differing assumptions. The cost indices are then compared with the

GNP deflator from 1965 to the most recent period available. Though the GNP deflator has only been used for one year to index the crude oil price, we make our comparison for the longer period to obtain a more reliable statistical base.

After the deflator and the cost index have been compared, we explain the differences between the two. The explanation focuses on the structure of the GNP deflator and pinpoints reasons why it might or might not be a good indicator of input prices for a single industry.

FINDINGS

During the period 1965 to 1976, costs tended to grow more rapidly than the GNP deflator, with the most pronounced differences appearing since 1970. For example, the cost index calculated from government price data grew at an annual rate of 7.2% from 1965 to the second quarter of 1976. Over this same period, the GNP deflator grew at an annual average of 5.5%. Since the first quarter of 1970, this version of the cost index grew at about 9.2% compared to 6.5% for the deflator, a difference of 2.7 percentage points per year. While these annual differences may seem modest, their continued existence can become important. Since the first quarter of 1970, the cost index grew by 73% compared to 48% for the GNP deflator.

In addition, the GNP deflator is not a good measure of input costs for any commodity. It is a measure of the prices of final goods and services, and so can measure only indirectly the cost of labor and other inputs. To be sure, it reflects these costs as they are included in final prices. Still, there are several reasons why changes in input costs and changes in the price of final goods may be different: delays between cost changes and price changes, and changes in productivity. Since delays and productivity changes for any single commodity may be different than for the "average" commodity, the GNP deflator may give a misleading picture of changes in input prices for any single product. Our research suggests that the deflator gives a misleading picture of changes in crude oil input prices.

A COST INDEX FOR CRUDE OIL INPUTS

In this section, we derive a cost index for inputs used in discovering and producing crude oil. We then compare this index with the GNP deflator and discuss possible explanations for any differences between the index and the deflator.

The cost index is estimated using two sets of data, one drawn from government sources, the other drawn from industry sources. As initially calculated, the cost index ignores several complicating factors in the investment decision, namely the spread over time of expenditures and revenue corresponding to a given unit of investment, and the tax treatment of revenue. An adjusted cost index is derived to take these factors into account. It turns out that these adjustments do not have a major effect except when tax treatment changes sharply. Thus, the choice between the adjusted and unadjusted indices rests primarily on whether it is desired to include tax changes in input costs. In this section we concentrate on the unadjusted index. The adjusted index is described in detail in appendix B.

Before constructing our index of cost, we reviewed a number of existing indices. Though these do not exactly match the requirements of this project, they summarize a great deal of useful information. We discuss them briefly in the following sections, then turn to the description of our cost index and its comparison to the GNP deflator.

EARLIER COST INDICES

There are at least four widely used indices of crude petroleum costs. One is a price index for inputs used in drilling and equipping new wells, constructed by the Independent Petroleum Association of America (IPAA). The second is based on a survey of expenditure for crude oil exploration, development and production. The survey, termed the Joint Association Survey (JAS), is administered by the leading petroleum trade associations. The third is a measure of the long run cost per barrel of new oil, prepared by the firm LaRue, Moore and Schafer (LMS). The fourth is the wholesale price index of oil field machinery and equipment published by the Bureau of Labor Statistics.

The IPAA Index of the Costs of Drilling and Equipping New Wells

The drilling and equipping cost index is constructed annually by the cost committee of the IPAA [3]. The index measures only costs incurred after drilling begins and before the process is completed by installing the "Christmas tree."

The IPAA index is formed from two separate parts. One part measures the cost of services that operators normally contract out and are reported variously as a cost per day or a cost per foot. Data on these costs are collected in an annual IPAA survey.

The other part of the index represents direct costs to operators. This is a weighted average of price indices for inputs purchased directly by operators. The weights are based on a detailed survey taken every five years. The price indices used for separate inputs are obtained from a number of different sources including government publications, industry publications and operator's contracts with service and equipment companies.

The IPAA cost index is similar in concept to the cost index constructed in this paper. The portion of the IPAA index measuring direct purchases is especially close, since it measures the cost of a fixed bundle of inputs.

However, the IPAA index is not a complete measure of input costs. A number of expenditure categories are not covered. The excluded categories include geological and geophysical expenditures, overhead, improved recovery programs, production costs and others. A recent FEA study [1] points out that the type of costs covered by the IPAA index were, in 1973, about 23% of total expenditures on finding and producing crude oil.

The Joint Association Survey of Expenditure on Exploration, Development, and Production

The Joint Association Survey [2] is performed by three petroleum trade associations, the American Petroleum Institute, the Independent Petroleum Association of America and the Mid-Continent Oil and Gas Association. The respondents to the survey are a large number (364 in 1974) of companies engaged in exploration, development, and production. In 1974, respondents accounted for 77 percent of total revenues from oil and gas. Estimates of expenditures for non-reporting companies were made using statistical techniques, and were included in the total.

As the name implies, this source provides total expenditures rather than expenditures per unit of input or output. A crude index of expenditures per unit output can be constructed by dividing expenditures by a rough measure of output such as additions to reserves. However, there is a serious drawback to using this measure for the purposes of this study. As noted earlier, we are attempting to isolate only one source of cost changes: changes in the prices of inputs. A measure of expenditure per unit of additional reserves would include both input price changes, which we are attempting to measure, and changes in the difficulty of finding new oil, which we do not want to include.

We do, in fact, make use of this expenditure data in constructing one version of our index. To isolate input price changes, we divide expenditure in individual categories by some measure of the quantity of inputs purchased.

The Joint Association Survey data include costs spent in a given year rather than the costs of finding and producing a given vintage of oil. The latter costs will be spread

over a number of years. A cost index based on the JAS data but taking into account the spread of expenditures over time is presented by LaRue, Moore and Schafer. This is discussed next.

A Measure of New Oil Costs Presented by LaRue, Moore and Schafer(LMS)

The LMS measure is an estimate of the total economic cost of finding and producing a typical barrel of oil of specific vintage [4]. The calculations use expenditure data from the JAS survey to estimate the price that would yield a 15% after tax return on investment. This price is defined as the cost of new oil, under the assumption that the 15% return is a necessary cost to attract investment funds.

The LMS cost estimates indicate that since 1960 the price of new oil has been below cost. The disparity increased from 1960 to 1973, then narrowed in 1974. Drilling activity fell fairly steadily throughout the period, then picked up in 1974. That drilling increased while the price was below measured cost indicates that investment may not always require a 15% after tax return or that the price is not expected to remain constant. Still, the upturn in drilling does suggest that oil supply responds to economic incentives.

The LMS cost index is more general than the index we construct. Like the JAS data on which it is based, it includes changes in the difficulty of finding oil as well as pure inflation in the price of inputs.

The LMS definition of cost has the effect of including in cost a given percentage rate-of-return to capital. We also use this methodology when calculating one version of our index.

The Wholesale Price Index for Oil Field Drilling Machinery and Equipment

The wholesale price index for oil field drilling machinery and equipment is published by the Bureau of Labor Statistics [7]. The index includes prices for several specific types of machinery, such as portable drilling rigs and slush pumps. The main advantage of this index over the other indices discussed is that it is available almost immediately. Unfortunately, it covers only a few of the inputs used to discover and produce oil.

THE PROPOSED COST INDEX

The cost index we construct is defined as the cost of a fixed bundle of inputs, in different years, divided by the cost of those same inputs in a reference year. The bundle of inputs is defined as those inputs actually purchased in a specified base year. The procedure results in a so-called Laspeyres index of input prices.

The calculation procedure described above requires the price of each item for each year, and the physical quantity bought in the base year. In practice, the index is calculated in an equivalent form. Each price is divided by the base year price, forming a price index for each input. The price indices are then averaged using as weights the share of each item in the base-year costs.

THE COST INDEX BASED ON GOVERNMENT DATA

The index based on government data uses government sources both for cost weights and for price indices. The weights are formed by combining data from several sources. The share in cost for individual materials and supplies are taken from the Input-Output Structure of the U.S. Economy [6], published by the Department of Commerce. These cost shares omit a large fraction of the value of final product, called value added. Part of this value added is employment cost, data on which are available in The Census of Mineral Industries [5]. Since the most recent published version of the Input-Output Structure is for the year 1967, we use weights for this year.

Table 1 summarizes the share of each input in the value of 1967 crude oil output. The weights used in the index are derived from these shares as described below. These derived weights are also presented in the table, along with a description of the price index used for each input. The values of the price indices for various periods are listed in appendix A.

In creating the cost index, we omit several inputs whose prices depend primarily on the demand for or the price of petroleum. Inputs omitted for this reason include land for future exploration (real estate), crude petroleum and natural gas, refined petroleum and related products, and electric and gas utilities. In addition, several inputs of minor importance were omitted because there seemed to be no good price measure.

Value added except for labor costs is also omitted. This represents the return on invested capital, and taxes. Covering costs, including a constant percentage return on invested funds, means maintaining a constant ratio between the price of output and the price of purchased inputs. Hence, our cost index can be calculated directly from the rate of increase in the prices of purchased inputs.

After omitting the inputs discussed above, the remaining weights are adjusted to sum to one.

Comparison of the GNP Deflator and the Cost Index Based on Government Data

The cost index constructed from government data was calculated annually from 1965 to 1969, then quarterly from the first quarter of 1970 (1970-I) to 1976-II. The index is compared with the deflator in figure 1 and in table 2. In this comparison, both the cost index and the deflator take value 1 in 1965.

TABLE 1

WEIGHTS AND PRICE INDICES USED FOR THE COST INDEX AS CALCULATED FROM GOVERNMENT DATA

	1967 weight in total revenue	Weight in cost index	Price index
I. COST OF SUPPLIES			
Crude petroleum and natural gas	.02487	.00000	[1]
Industrial organic and inorganic chemicals	.00911	.04175	WPI industrial chemicals [2]
Miscellaneous chemical products	.00179	.00820	Price index for output of SIC 2892 explosives [2]
Paints and allied products	.00059	.00270	WPI prepared paint [2]
Petroleum refining and related products	.0022	.00000	[1]
Reclaimed rubber and mis. rubber products	.0018	.00000	[3]
Gaskets and insulations	.00412	.01888	WPI insulation material [2]
Hand and edge tools including saws	.00065	.00000	[3]
Machine shop products	.00532	.02438	WPI machine shop products [2]
Mechanical measuring devices	.00062	.00284	WPI precision measuring tools [2]
Railroads and related services	.00154	.00706	Revenue per ton mile - railroads [4]
Motor freight transportation	.0012	.00550	Revenue per ton mile - trucking [4]
Water transportation	.00665	.03043	Revenue per ton mile - water transportation [4]
Communications	.00082	.00376	CPI residential telephone service [5]
Electric utilities	.00774	.00000	[1]
Gas utilities	.00287	.00000	[1]
Wholesale trade	.00802	.03675	WPI - industrial commodities [2]
Retail trade	.00361	.01654	CPI - durable commodities [5]
Banking	.00354	.00000	[3]
Insurance carriers	.00245	.01123	CPI - insurance and finance [5]
Miscellaneous business services	.00801	.00000	[3]
Miscellaneous professional services	.00808	.03703	Average weekly earnings - professional and technical workers [6]
Automobile repair and services	.00114	.00522	CPI auto repairs [5]
Transferred imports	.07159	.00000	[1]
Business travel, entertainment and gifts	.00576	.00000	[3]
Scrap used and second-hand goods	.00573	.00000	[3]
II. CAPITAL EXPENDITURES			
Maintenance and repair construction	.03168	.14520	GNP deflator for fixed investment in oil and gas wells [7]
Cement, hydraulic	.0014	.00642	Price index for SIC 3241 - cement, hydraulic [2]
Blast furnace and basic steel products	.00796	.03648	Price index for SIC 3312 - blast furnace and steel mills [2]
Fabricated plate work	.0029	.01329	WPI metal tanks [2]
Pipe, valves and pipe fittings	.00351	.01609	Price index for SIC 3498 fabricated pipes [2]
Internal combustion engines	.00323	.01480	Price index for SIC 3519 internal combustion engines [2]
Construction machinery	.0009	.00412	WPI construction machinery and equipment [2]
Oil field industry	.0029	.01329	Price index for SIC 3533 oil field machinery and equipment [2]
Pumps and compressors	.0047	.02154	WPI pumps, compressors and equipment [2]
Power transmission equipment	.00059	.00270	WPI mechanical power transmission equipment [2]
Switch gear and switchboard apparatus	.00216	.00000	[3]
Motors and generators	.00552	.02530	WPI motors, generators, motor generators [2]
Industrial controls	.00101	.00463	WPI industrial controls [2]
Welding apparatus	.00131	.00000	[3]
III. LABOR COSTS			
Production, development and exploration workers	.03753	.17200	Average hourly earnings - crude oil production workers [8]
Other payroll	.05189	.23780	Average weekly earnings - professional and technical workers [6]
Supplemental labor costs	.00743	.03405	[9]
IV. REAL ESTATE COSTS	.16161	.00000	[1]
V. REMAINING VALUE ADDED	.48495		

REFERENCES FOR TABLE 1

[1] Eliminated from index for reasons discussed in text.

[2] Wholesale Prices and Price Indexes, BLS: various issues.

[3] Eliminated from index because price index was not available or was available only for a small portion of the period 1965-1976.

[4] Transport Economics, ICC: various issues. Quarterly data interpolated from annual values except for railroads where a price index for railroad freight (BLS) was used from 1970 on.

[5] Consumer Price Index, BLS: various issues.

[6] National Survey of Professional, Administrative, Technical and Clerical Pay, BLS: various years. Weighted average of salaries of accountants, engineers and engineering technicians. Quarterly data interpolated from annual values.

[7] Unpublished Commerce Department data. Quarterly data interpolated from annual values.

[8] Employment and Earnings, BLS: various issues.

[9] Supplement as a percentage of wages and salaries multiplied by average hourly earnings - crude oil production workers. Supplements are the national average from National Income and Product Accounts, Dept. of Commerce.

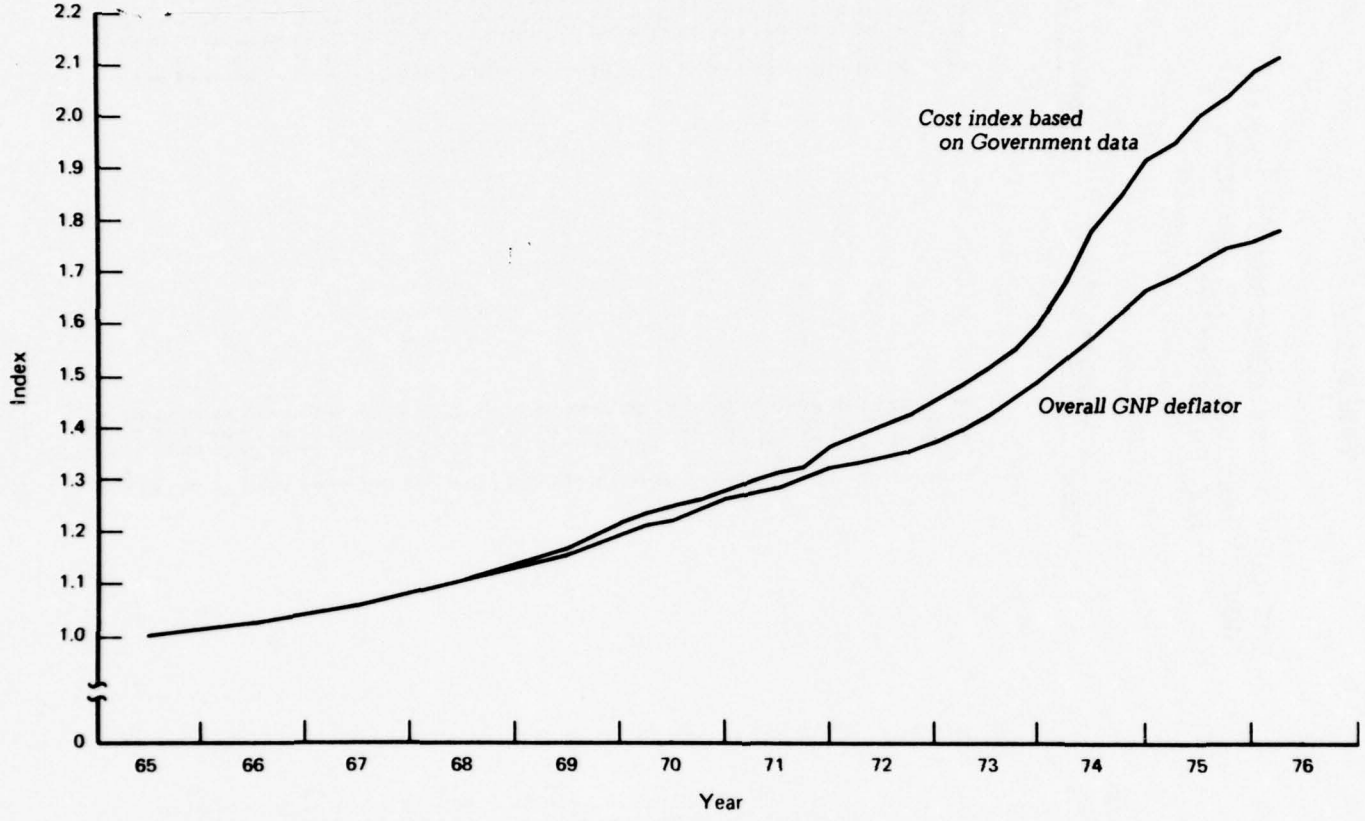

FIG. 1: COMPARISON OF COST INDEX BASED ON GOVERNMENT DATA AND OVERALL GNP DEFLATOR: 1965-1976

TABLE 2

THE COST INDEX CONSTRUCTED FROM
GOVERNMENT DATA COMPARED WITH
THE GNP DEFLATOR

Year or Quarter	Cost Index	GNP Deflator
1965	1	1
1966	1.034	1.034
1967	1.066	1.063
1968	1.116	1.112
1969	1.175	1.167
1970-I	1.226	1.209
1970-II	1.241	1.223
1970-III	1.258	1.234
1970-IV	1.268	1.252
1971-I	1.288	1.271
1971-II	1.303	1.288
1971-III	1.322	1.299
1971-IV	1.338	1.311
1972-I	1.376	1.330
1972-II	1.397	1.339
1972-III	1.416	1.350
1972-IV	1.432	1.365
1973-I	1.463	1.385
1973-II	1.488	1.409
1973-III	1.520	1.435
1973-IV	1.554	1.468
1974-I	1.618	1.502
1974-II	1.696	1.542
1974-III	1.793	1.588
1974-IV	1.855	1.637
1975-I	1.925	1.677
1975-II	1.959	1.694
1975-III	2.002	1.724
1975-IV	2.040	1.754
1976-I	2.095	1.767
1976-II	2.121	1.787

The GNP deflator moves closely with the cost index through the middle of 1971, but thereafter, it lags the growth in costs. Over the entire period, 1965 to 1976-II, the deflator grows at an average annual rate of 5.5% compared with 7.2% for the cost index. Over the last part of the period, from 1970-I to 1976-II, the GNP deflator grew at an annual rate of 6.5% compared with 9.2% for the cost index.

THE COST INDEX BASED ON INDUSTRY DATA

To check the robustness of our results, we duplicated them as closely as possible using data from the petroleum industry. The distinction between government and industry sources is not so sharp as it may seem. Indeed, much government data is collected from the industry. Nevertheless, what we call industry data does represent a distinct source of information with which to duplicate our earlier calculations.

The weights for the industry index are based on the 1974 Joint Association Survey [2]. As mentioned earlier, this source records expenditures by major category (exploration, development and production) and by detailed subcategory. The categorization divides expenditures by function rather than by type of input purchased. For example, one category is drilling and equipping development wells rather than pipe, valves and pipe fittings.

Because the categorization does not isolate separate inputs, price indices for the individual categories are not available. Instead, we use expenditures in each category divided by a measure of input quantity. For example, our estimate of a price index for geological and geophysical activity is expenditure in this category divided by the number of man-months of crews engaged in geophysical exploration. A complete listing of the categories, the weights, and a description of the price measures, is provided in table 3. The data from which the price measures are calculated are presented in appendix A.

As before, several input categories are omitted and the weights recalculated. The omitted categories include "remaining value added," payments for acquiring undeveloped acreage, and production taxes. The revised weights are listed in table 3 along with the original weights.

Comparison of the GNP Deflator and the Cost Index Based on Industry Data

The cost index based on industry data is estimated annually from 1965 to 1974. The index is compared with the GNP deflator in figure 2 and table 4. The GNP deflator lags sharply behind the cost index in 1966, then moves at about some rate between 1966 and 1972. After 1972 the deflator again lags behind the cost index. Overall, between 1965 and 1974 the deflator increases by an annual average of 5.1% while the cost index increases by an annual average of 7.9%. Between 1970 and 1974 the deflator grows by an average of 6.3% while the cost index increases by 10.8%.

TABLE 3

WEIGHTS AND PRICE INDICES USED FOR THE COST INDEX AS CALCULATED FROM INDUSTRY DATA

	1974 Weight in Total Expenditure	Weight in Cost Index	Price Index
I. EXPLORATION			
Drilling and equipping exploration wells	.0585	.13946	JAS cost per foot of drilling and equipping wells [1]
Acquiring undeveloped acreage	.201	.00000	[2]
Lease rentals	.00661	.01576	JAS expenditures deflated by index of production [3]
Geological and geophysical	.02273	.05419	JAS expenditures deflated by crew months of geophysical activity [3]
Contribution toward test wells	.00121	.00288	JAS expenditures deflated by crew months of geophysical activity [3]
Land department - leasing and scouting	.00416	.00992	JAS expenditures deflated by crew months of geophysical activity [3]
Other - incl direct overhead	.0082	.01955	JAS total overhead expenditures deflated by total employment [3]
G&A overhead allocated to exploration	.01375	.03278	JAS total overhead expenditures deflated by total employment [3]
II. DEVELOPMENT			
Drilling and equipping development wells	.09540	.22742	JAS cost per foot of drilling and equipping wells [1]
Lease equipment	.02735	.06520	WPI oilfield machinery and equipment [4]
Improved recovery programs	.01417	.03378	JAS expenditures deflated by index of production [3]
Other - incl. direct overhead	.01240	.02956	JAS total overhead expenditures deflated by total employment [3]
G&A overhead allocated to development	.00966	.02302	JAS total overhead expenditures deflated by total employment [3]
III. PRODUCTION			
Production expenditures and direct overhead	.1246	.29703	JAS expenditures deflated by index of production [3]
Production of severance taxes	.04294	.00000	[5]
Ad Valorem taxes	.01364	.00000	[5]
G&A overhead allocated to production	.02074	.04944	JAS total overhead expenditures deflated by total employment [3]
IV. REMAINING VALUE ADDED	.32294		

REFERENCES FOR TABLE 3

[1] Joint Association Survey of the U.S. Oil and Gas Producing Industry: various issues.

[2] Eliminated from index for reason given in text.

[3] Expenditures come from Joint Association Summary of the U.S. Producing Industry: various years. Crew month of geophysical activity comes from Geophysics: various issues. Index of crude oil production comes from Twentieth Century Petroleum Statistics, DeGolyer and MacNaughton. Total employment comes from Employment and Earnings: various issues.

[4] Wholesale Prices and Price Indexes: various issues.

[5] Eliminated to make index comparable with government sources.

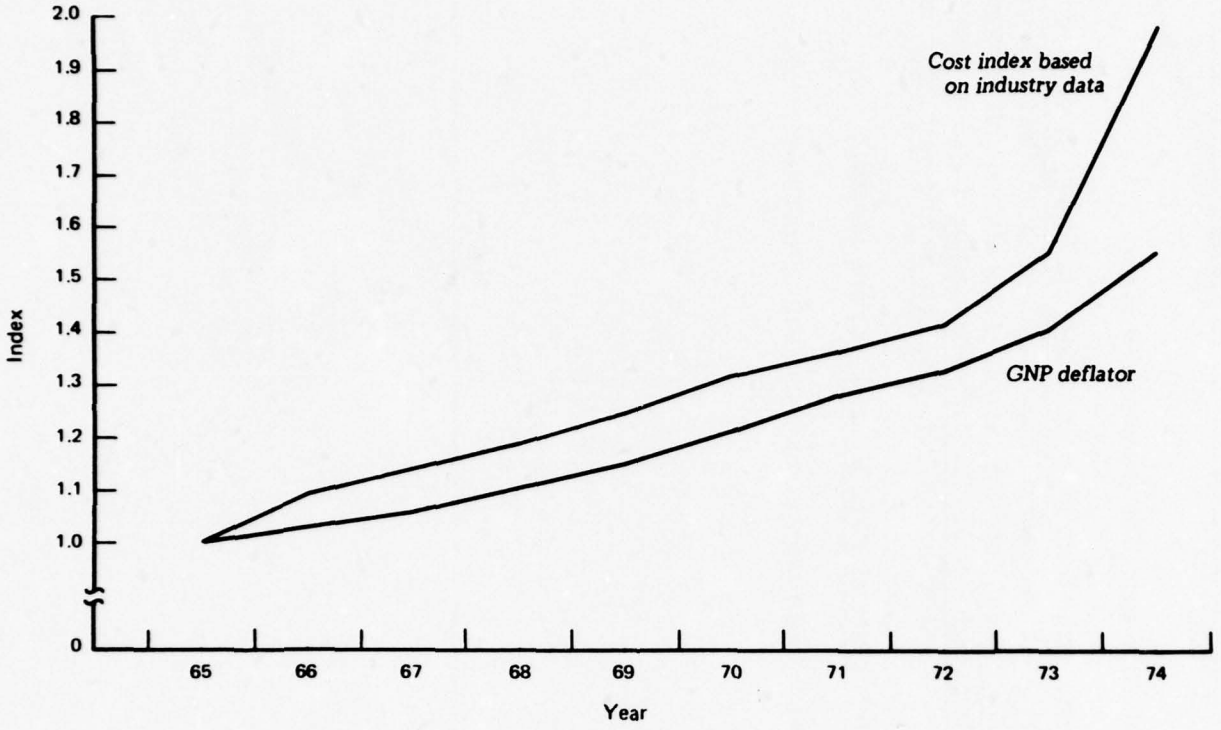

FIG. 2: COMPARISON OF COST INDEX BASED ON INDUSTRY DATA AND OVERALL GNP DEFLATOR: 1965-1974

TABLE 4

A COMPARISON OF THE COST INDEX CONSTRUCTED FROM INDUSTRY DATA AND THE GNP DEFLATOR

Year	Cost index	GNP deflator
1965	1	1
1966	1.098	1.034
1967	1.141	1.063
1968	1.198	1.112
1969	1.259	1.167
1970	1.321	1.229
1971	1.367	1.292
1972	1.426	1.346
1973	1.558	1.424
1974	1.989	1.567

Comparison of the Cost Index Based on Government Data and the Cost Index Based on Industry Data

Both versions of the cost index, one based on government data, the other on industry data, increase more rapidly than the GNP deflator. However, the two versions do not always grow at the same rate, as can be seen from figure 3. For example, the industry index jumps by about 10% in 1966. The government index increases much less. This, and other differences are not surprising, since the two indices are based on entirely different data.

THE ADJUSTED COST INDEX

Both cost indices described above leave out factors that may be important in the decision of whether to invest in searching for new oil. To see whether these omissions are important, we calculated a more complex form of the index that takes two facts about the investment decision into account. First, expenditures and receipts do not take place all at once, but are spread over time. Second, the tax treatment of revenue affects the investment decision.

The adjusted index is calculated using the same two data sources discussed earlier. One version of the adjusted index is calculated using government data, the other is calculated using industry data. The derivation of the adjusted index, and the results, are presented in appendix B. We simply note here that the adjusted indices follow closely the unadjusted cost indices described above except for times when tax treatment of oil has suddenly become less favorable. At these times, the adjusted indices shift relative to the unadjusted ones.

A SUMMARY OF GROWTH RATES FOR COST INDICES ESTIMATED IN THIS STUDY

Because of data limitations, the different cost indices were not calculated for identical periods. Still, some rough comparisons between indices are possible as shown in table 5. From 1965 to 1970, the adjusted cost indices grew more rapidly than the unadjusted ones, by about 1 to 1.5 percentage points annually. This suggests that tax treatment can make a difference. For this period, the indices based on industry data grew more rapidly than the indices based on government data. All four cost indices grew more rapidly than the GNP deflator though the differences were not always pronounced.

Since 1970, the cost indices all grew much more rapidly than the GNP deflator. Their growth rates range from 9.2% annually to 10.8% compared to 6.5% for the deflator. The index based on government data spans a major change in tax treatment. Hence, the adjusted version grew more rapidly than the unadjusted version.

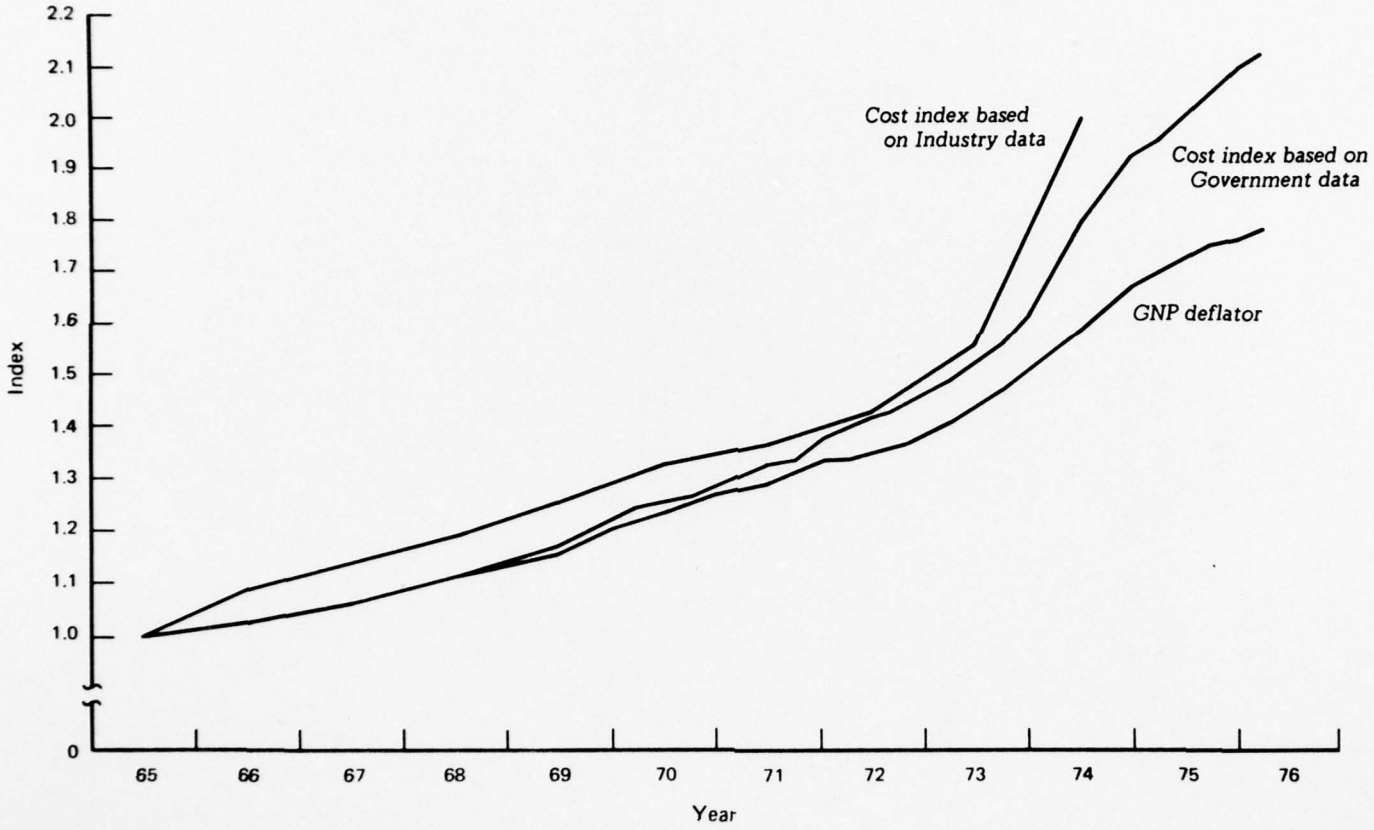

FIG. 3: COMPARISON OF COST INDEX BASED ON INDUSTRY DATA, COST INDEX BASED ON GOVERNMENT DATA AND GNP DEFLATOR: 1965-1976

TABLE 5

A COMPARISON OF ANNUAL GROWTH RATES
FOR COST INDICES AND THE GNP DEFLATOR

Index	1965 to 1970-I	1970-I to 1976-II
Cost index based on government data	4.5%	9.2%
Adjusted cost index based on government data	5.7	10.5
GNP deflator	4.2	6.5

	1965 to 1970	1970 to 1974
Cost index based on industry data	5.7	10.8
Adjusted cost index based on industry data	7.1	10.3
GNP deflator	4.2	6.3

POSSIBLE REASONS FOR THE DIVERGENCE BETWEEN THE COST INDICES AND THE GNP DEFLATOR

The evidence presented above suggests that the GNP deflator understates inflation in the prices of inputs used in the exploration and production of crude petroleum. This finding should not be considered surprising in view of the way the GNP deflator is constructed.

How the GNP Deflator is Constructed

The GNP deflator is a price index meant to represent the average price of all final goods and services. The index is most easily visualized as the ratio of current GNP to "real" GNP, or GNP in 1972 dollars. Real GNP is calculated by dividing GNP into separate components, dividing each component by an appropriate price index, and summing the deflated components.

The individual prices used in calculating the GNP deflator are wholesale price indices or consumer price indices of specific commodities. When these are not available, unit values (expenditure divided by quantity) are used. When better measures are not available, as in the case of certain government services, an index of earnings per employee may be used.

The Deflator is an Average of Separate Items

The GNP deflator does not purport to measure inflation in any specific sector of the economy but is an average of a number of different rates of inflation. Still, it could be used as a rough indicator of inflation in specific sectors if the prices being averaged moved closely together. To see if the prices did move together, we graphed the GNP deflator against several of its major components. As can be seen from figure 4, the components do grow at distinct rates and their average, the deflator, is not a precise measure of the individual prices.

Of these components, the deflator for non-residential structures is of special interest because it uses inputs similar to those used in exploring for and producing crude petroleum. In recent years, the growth in the deflator for non-residential structures has exceeded the growth of the overall deflator, but has been close to the growth of our cost index based on government data. Between 1970-I and 1976-II, the non-residential deflator grew at an average annual rate of 8.8% compared to 6.5% for the overall deflator and 9.2% for the unadjusted cost index based on government data.

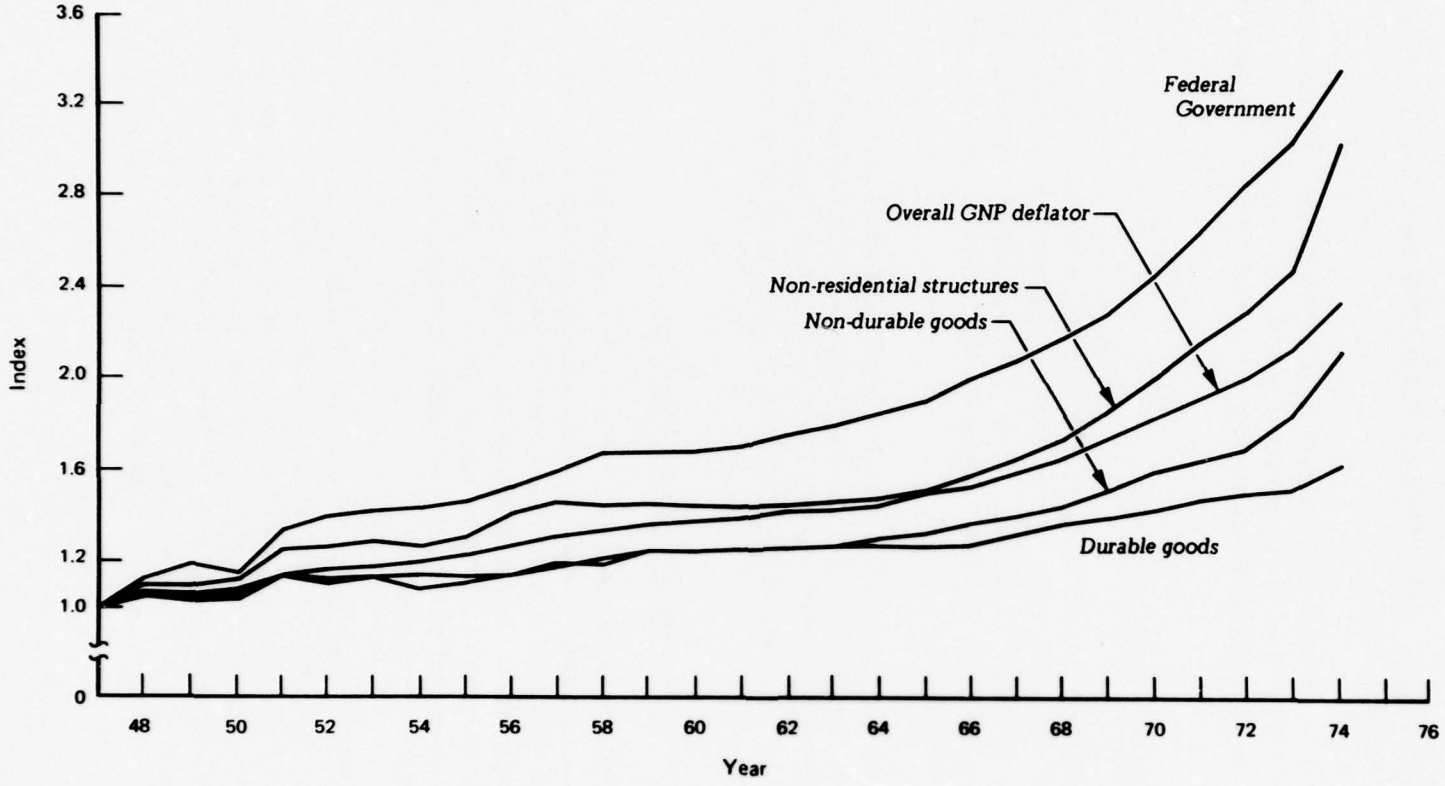

FIG. 4: COMPARISON OF OVERALL GNP IMPLICIT PRICE DEFLATOR AND SEVERAL OF ITS COMPONENTS: 1948-1974

The GNP Deflator is an Indirect Measure of Input Prices

The GNP deflator includes the prices of final goods only, and hence explicitly excludes the prices of most inputs into final goods. Still, it can be argued that the deflator indirectly measures input prices since prices tend to follow costs. However, the relation between input prices and output prices is not always close, especially if productivity is changing or there are lags in passing cost changes through to consumers. When productivity is increasing in the economy as a whole, the GNP deflator will under-represent the growth of input prices.

CONCLUSION

The inflation adjustment, established by the Energy Policy and Conservation Act in 1975, allowed the controlled price of crude oil to grow by the same annual percentage as the GNP deflator, up to a limit of 7%. An additional adjustment up to 3% per year was also allowed. Though the inflation adjustment has recently been somewhat modified, it will revert to its original form as of March 1977. The supplemental adjustment of up to 3% will be dropped, unless Congress acts to maintain it.

If the reason for indexing the controlled price is to maintain exploration and production incentives during inflation, the GNP deflator is not the best index to use; the deflator does not match changes in the prices of inputs used in exploring for and producing crude petroleum. Crude oil price adjustments based on the deflator lag behind these changes and allow incentives to be eroded.

To evaluate the inflation adjustment, we constructed an index of input costs for crude oil. The index was calculated in several different forms, as a check of its sensitivity to specific assumptions and data sets. All forms of our cost index grew more rapidly than the GNP deflator after 1970. For example, between the first quarter of 1970 and the second quarter of 1976, what we call the unadjusted cost index, calculated using government data, grew at an average rate of 9.2% per year, the GNP deflator grew by an average rate of 6.5% per year. During the whole period, the unadjusted cost index grew by 73% while the deflator grew by 48%. The same cost index, adjusted to include the effect of taxes, grew even more rapidly relative to the GNP deflator than the unadjusted index.

The results of this study suggest that in recent years, growth of the GNP deflator has not kept up with growth in crude petroleum input prices. One reason for the lag is that the deflator is an average of a number of prices. It may be a reasonable measure of inflation in the economy as a whole, but it does not purport to measure inflation in any particular sector. A second reason is that the deflator measures only the prices of final goods. Though the prices of final goods depend strongly on the prices of inputs, changes in input prices are not immediately reflected in output prices. An important feature in modifying the relationship is the rate of productivity increase, and there is little reason to believe that productivity growth in crude petroleum is the same as for the economy as a whole.

We have argued that the GNP deflator is not as accurate a measure of changes in crude petroleum input costs as a more specific measure would be. Indeed, so simple an alternative as the GNP deflator for non-residential structures agrees more closely with our cost index for recent years. However, even a perfect inflation adjustment would miss many of the important determinants of incentives. Other factors that affect exploration and production are changes in the productivity of resources, the price of natural gas and, importantly, the mix of upper- and lower-tier oil.

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APPENDIX A

DATA USED TO CONSTRUCT COST INDICES

APPENDIX A

DATA USED TO CONSTRUCT COST INDICES

This appendix lists the data used in our cost indices. Table A-1 lists the values of the price indices used in the adjusted and unadjusted cost indices based on government data. Table A-2 lists the expenditure data used in the adjusted and unadjusted indices based on industry data. Table A-2 also lists the data on input quantity used to convert the expenditure in particular categories into expenditure per unit input.

The prices and weights used in the cost indices are described in the text and presented in tables 1 and 3. For convenience, these tables are repeated below as tables A-3 and A-4.

TABLE A-1

PRICE DATA USED TO CONSTRUCT COST INDEX
BASED ON GOVERNMENT DATA

Date	WPI industrial chemicals	Price index SIC 2892	WPI prepared paint	WPI insulation materials	WPI Machine shop products	WPI Precision measuring tools	Revenue per ton mile railroads
1965	1.___	1.___	1.___	1.___	1.___	1.___	1.___
1966	1.008	0.984	1.013	0.997	1.022	1.075	0.991
1967	1.025	1.003	1.037	1.039	1.051	1.090	1.001
1968	1.035	1.025	1.087	1.099	1.138	1.115	1.034
1969	1.028	1.046	1.131	1.199	1.205	1.138	1.062
1970-I	1.027	1.062	1.159	1.244	1.257	1.153	1.117
1970-II	1.031	1.066	1.165	1.281	1.269	1.170	1.134
1970-III	1.038	1.066	1.165	1.285	1.281	1.175	1.170
1970-IV	1.041	1.070	1.169	1.309	1.314	1.175	1.202
1971-I	1.046	1.131	1.189	1.311	1.347	1.177	1.267
1971-II	1.045	1.132	1.202	1.369	1.362	1.179	1.312
1971-III	1.050	1.131	1.202	1.398	1.366	1.179	1.313
1971-IV	1.043	1.131	1.202	1.398	1.366	1.189	1.311
1972-I	1.038	1.131	1.214	1.398	1.372	1.194	1.329
1972-II	1.039	1.145	1.227	1.441	1.402	1.198	1.340
1972-III	1.039	1.150	1.227	1.424	1.418	1.198	1.340
1972-IV	1.034	1.179	1.226	1.429	1.419	1.200	1.348
1973-I	1.043	1.179	1.240	1.432	1.434	1.213	1.353
1973-II	1.054	1.180	1.252	1.438	1.478	1.222	1.353
1973-III	1.063	1.180	1.256	1.427	1.486	1.222	1.368
1973-IV	1.082	1.254	1.323	1.413	1.491	1.237	1.420
1974-I	1.163	1.361	1.357	1.446	1.546	1.262	1.471
1974-II	1.422	1.430	1.445	1.512	1.623	1.291	1.534
1974-III	1.701	1.475	1.579	1.654	1.746	1.326	1.676
1974-IV	1.937	1.614	1.663	1.891	1.893	1.394	1.680
1975-I	2.072	1.710	1.702	1.971	2.003	1.467	1.682
1975-II	2.130	1.739	1.717	1.987	2.001	1.488	1.735
1975-III	2.126	1.742	1.742	2.104	2.021	1.513	1.865
1975-IV	2.155	1.806	1.763	2.093	2.065	1.528	1.919
1976-I	2.206	1.847	1.774	2.130	2.085	1.546	1.924
1976-II	2.239	1.835	1.795	2.189	2.137	1.551	1.982

TABLE A-1 (continued)

Date	Revenue per ton-mile Trucking	Revenue per ton-mile Water	CPI Residential Telephone	WPI Industrial Commodities	CPI Durable Commodities	CPI Insurance and Finance	CPI Auto Repairs
1965	1.___	1.___	1.___	1.___	1.___	1.___	1.___
1966	0.981	0.975	0.979	1.021	1.001	1.036	1.017
1967	1.028	0.864	0.992	1.037	1.016	1.083	1.058
1968	1.072	0.907	0.992	1.063	1.047	1.153	1.116
1969	1.096	0.929	1.004	1.099	1.087	1.285	1.187
1970-I	1.132	0.963	1.023	1.126	1.156	1.394	1.484
1970-II	1.147	0.977	1.040	1.136	1.176	1.446	1.511
1970-III	1.162	0.993	1.044	1.143	1.190	1.473	1.533
1970-IV	1.177	1.012	1.045	1.155	1.198	1.464	1.469
1971-I	1.193	1.032	1.047	1.167	1.169	1.384	1.330
1971-II	1.208	1.051	1.054	1.178	1.184	1.364	1.360
1971-III	1.219	1.062	1.089	1.191	1.193	1.383	1.384
1971-IV	1.224	1.064	1.095	1.193	1.191	1.400	1.392
1972-I	1.229	1.067	1.120	1.207	1.191	1.416	1.413
1972-II	1.234	1.070	1.132	1.219	1.203	1.423	1.424
1972-III	1.244	1.092	1.136	1.228	1.216	1.438	1.435
1972-IV	1.258	1.134	1.139	1.235	1.221	1.446	1.445
1973-I	1.271	1.177	1.141	1.259	1.219	1.448	1.474
1973-II	1.284	1.219	1.148	1.298	1.236	1.455	1.496
1973-III	1.303	1.276	1.157	1.314	1.244	1.484	1.514
1973-IV	1.329	1.348	1.175	1.351	1.252	1.552	1.535
1974-I	1.354	1.419	1.200	1.437	1.257	1.575	1.574
1974-II	1.380	1.490	1.201	1.558	1.306	1.595	1.620
1974-III	1.415	1.551	1.205	1.668	1.369	1.647	1.687
1974-IV	1.461	1.601	1.211	1.717	1.406	1.716	1.754
1975-I	1.507	1.651	1.215	1.745	1.428	1.751	1.820
1975-II	1.553	1.701	1.235	1.765	1.470	1.769	1.857
1975-III	1.592	1.745	1.25_	1.786	1.498	1.797	1.883
1975-IV	1.626	1.782	1.270	1.819	1.515	1.862	1.916
1976-I	1.660	1.819	1.272	1.847	1.520	1.925	1.965
1976-II	1.694	1.856	1.279	1.873	1.558	1.933	1.991

TABLE A-1 (continued)

Date	GNP Deflator Oil & Gas Wells	Price Index SIC 3241	Price Index SIC 3312	WPI Metal Tanks	Price Index SIC 3498	Price Index SIC 3519	WPI Construction Machinery
1965	1.___	1.___	1.___	1.___	1.___	1.___	1.___
1966	1.065	1.003	1.013	1.018	1.041	1.022	1.030
1967	1.109	1.019	1.024	1.035	1.088	1.051	1.068
1968	1.166	1.044	1.048	1.067	1.168	1.092	1.129
1969	1.229	1.076	1.096	1.114	1.253	1.135	1.179
1970-I	1.287	1.136	1.130	1.162	1.289	1.169	1.216
1970-II	1.309	1.137	1.161	1.200	1.290	1.173	1.222
1970-III	1.309	1.138	1.186	1.225	1.316	1.184	1.228
1970-IV	1.285	1.099	1.200	1.236	1.355	1.212	1.268
1971-I	1.263	1.219	1.206	1.257	1.393	1.223	1.287
1971-II	1.239	1.259	1.234	1.267	1.427	1.227	1.293
1971-III	1.261	1.298	1.299	1.278	1.479	1.239	1.301
1971-IV	1.329	1.302	1.314	1.283	1.487	1.249	1.306
1972-I	1.396	1.304	1.337	1.314	1.487	1.269	1.332
1972-II	1.464	1.342	1.340	1.314	1.487	1.275	1.342
1972-III	1.516	1.359	1.338	1.325	1.487	1.275	1.346
1972-IV	1.553	1.369	1.339	1.338	1.488	1.276	1.348
1973-I	1.592	1.373	1.359	1.375	1.516	1.283	1.362
1973-II	1.630	1.405	1.375	1.409	1.536	1.297	1.398
1973-III	1.712	1.405	1.378	1.420	1.582	1.303	1.403
1973-IV	1.836	1.409	1.390	1.436	1.610	1.330	1.422
1974-I	1.961	1.537	1.448	1.489	1.637	1.365	1.464
1974-II	2.085	1.588	1.670	1.643	1.808	1.418	1.545
1974-III	2.166	1.732	1.953	1.820	2.179	1.529	1.695
1974-IV	2.200	1.744	2.026	1.914	2.277	1.607	1.801
1975-I	2.236	1.922	2.084	1.935	2.369	1.707	1.922
1975-II	2.270	1.964	2.082	1.925	2.417	1.739	1.966
1975-III	2.306	1.993	2.073	1.918	2.431	1.770	1.986
1975-IV	2.341	2.000	2.140	1.931	2.482	1.825	2.038
1976-I	2.375	2.077	2.145	1.954	2.502	1.865	2.073
1976-II	2.395	2.161	2.176	1.954	2.574	1.885	2.098

TABLE A-1 (continued)

Date	Price Index SIC 3533	WPI Pumps Compressor and Equipment	WPI Mechanical Power & Trans Equipment	WPI Motor Generator Etc.	WPI Industrial Controls	Average Hourly Earnings Crude Oil	Supplemental Labor Costs	Average Weekly Earnings Professional and Technical Workers
1965	1.___	1.___	1.___	1.___	1.___	1.___	1.___	1.___
1966	1.016	1.062	1.027	1.022	1.022	1.033	1.118	1.032
1967	1.052	1.109	1.052	1.073	1.051	1.072	1.173	1.079
1968	1.118	1.159	1.082	1.088	1.025	1.119	1.260	1.137
1969	1.183	1.217	1.125	1.159	1.021	1.188	1.375	1.202
1970-I	1.226	1.247	1.173	1.220	1.032	1.254	1.472	1.249
1970-II	1.244	1.250	1.211	1.249	1.025	1.250	1.500	1.267
1970-III	1.261	1.289	1.226	1.272	1.100	1.273	1.541	1.287
1970-IV	1.278	1.317	1.250	1.277	1.110	1.283	1.579	1.308
1970-I	1.283	1.330	1.256	1.287	1.109	1.343	1.694	1.329
1971-II	1.301	1.351	1.264	1.286	1.108	1.369	1.743	1.350
1971-III	1.304	1.356	1.272	1.294	1.157	1.382	1.774	1.370
1971-IV	1.304	1.357	1.273	1.296	1.177	1.386	1.777	1.390
1972-I	1.321	1.365	1.275	1.302	1.178	1.465	1.958	1.410
1972-II	1.346	1.371	1.303	1.318	1.179	1.471	1.982	1.430
1972-III	1.363	1.384	1.325	1.332	1.179	1.485	2.017	1.449
1972-IV	1.365	1.385	1.335	1.333	1.179	1.501	2.038	1.469
1973-I	1.377	1.388	1.341	1.344	1.179	1.544	2.260	1.488
1973-II	1.404	1.405	1.358	1.372	1.179	1.567	2.291	1.508
1973-III	1.414	1.416	1.366	1.387	1.179	1.607	2.368	1.530
1973-IV	1.422	1.449	1.389	1.398	1.179	1.607	2.385	1.554
1974-I	1.470	1.483	1.414	1.434	1.220	1.686	2.555	1.579
1974-II	1.607	1.587	1.472	1.482	1.311	1.722	2.628	1.603
1974-III	1.729	1.778	1.613	1.608	1.372	1.798	2.763	1.633
1974-IV	1.913	1.942	1.736	1.730	1.507	1.815	2.809	1.669
1975-I	1.998	2.032	1.779	1.811	1.510	1.930	3.048	1.706
1975-II	2.089	2.074	1.824	1.855	1.510	1.960	3.114	1.742
1975-III	2.126	2.093	1.851	1.910	1.520	2.029	3.246	1.787
1975-IV	2.228	2.117	1.859	1.947	1.562	2.059	3.270	1.833
1976-I	2.281	2.156	1.901	2.019	1.539	2.165	3.506	1.878
1976-II	2.302	2.184	1.941	2.033	1.539	2.151	3.510	1.923

TABLE A-2

DATA USED TO CONSTRUCT COST INDEX BASED ON INDUSTRY DATA
1965-1974

ITEM	YEAR									
	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
JAS Cost per foot for drilling and equipping wells ($)	13.44	14.95	15.97	16.83	17.56	18.84	19.03	20.76	22.50	28.93
JAS Expenditures for lease rentals and expense for carrying leases ($M)	166	180	140	179	134	138	143	142	155	186
JAS Expenditures for geological and geophysical activity ($M)	355	378	392	373	387	349	361	372	429	640
JAS Expenditures for contributions toward test wells ($M)	31	28	34	34	33	30	24	35	38	34
JAS Expenditures for land department, leasing & scouting ($M)	102	70	86	82	93	98	100	105	102	117
JAS Expenditures for other exploration costs, including direct overhead ($M)	61	128	122	136	168	143	142	147	181	231
JAS Expenditures for G&A overhead allocated to exploration ($M)	207	195	206	204	210	189	206	239	293	387
WPI Oilfield machinery and equipment (1965 = 100)	100	101.7	105.3	111.9	118.3	125.3	129.8	135.0	140.5	168.0
JAS Expenditures for improved recovery programs ($M)	124	187	247	222	303	285	323	310	276	399
JAS Expenditures for other development costs including direct overhead ($M)	78	119	167	188	180	170	185	160	189	349
JAS Expenditures for G&A overhead allocated to development ($M)	170	168	162	199	207	220	202	257	250	272
JAS Expenditures for production including direct overhead ($M)	1685	1895	1933	2094	2189	2379	2504	2563	2792	3508
JAS Expenditure for G&A overhead allocated to production ($M)	317	310	303	340	369	416	465	467	485	584
Crew months of geophysical activity - total ground activity	4471	3835	3496	3390	3259	2521	2755	3140	2999	3660
Index of production (1965 = 100)	100	106.6	113.1	116.3	118.9	123.6	121.6	122.2	118.6	113
Total employment - crude petroleum and natural gas fields (thousands)	156.6	152.5	149.7	148.1	145.8	144.2	142.5	142.7	142.1	148.5

TABLE A-3

WEIGHTS AND PRICE INDICES USED FOR THE COST INDEX AS CALCULATED FROM GOVERNMENT DATA

	1967 weight in total revenue	Weight in cost index	Price index
I. COST OF SUPPLIES			
Crude petroleum and natural gas	.02487	.00000	[1]
Industrial organic and inorganic chemicals	.00911	.04175	WPI industrial chemicals [2]
Miscellaneous chemical products	.00179	.00820	Price index for output of SIC 2892 explosives [2]
Paints and allied products	.00059	.00270	WPI prepared paint [2]
Petroleum refining and related products	.0022	.00000	[1]
Reclaimed rubber and mis. rubber products	.0018	.00000	[3]
Gaskets and insulations	.00412	.01888	WPI insulation material [2]
Hand and edge tools including saws	.00065	.00000	[3]
Machine shop products	.00532	.02438	WPI machine shop products [2]
Mechanical measuring devices	.00062	.00284	WPI precision measuring tools [2]
Railroads and related services	.00154	.00706	Revenue per ton mile - railroads [4]
Motor freight transportation	.0012	.00550	Revenue per ton mile - trucking [4]
Water transportation	.00665	.03048	Revenue per ton mile - water transportation [4]
Communications	.00082	.00376	CPI residential telephone service [5]
Electric utilities	.00774	.00000	[1]
Gas utilities	.00287	.00000	[1]
Wholesale trade	.00802	.03675	WPI - industrial commodities [2]
Retail trade	.00361	.01654	CPI - durable commodities [5]
Banking	.00354	.00000	[3]
Insurance carriers	.00245	.01123	CPI - insurance and finance [5]
Miscellaneous business services	.00801	.00000	[3]
Miscellaneous professional services	.00808	.03703	Average weekly earnings - professional and technical workers [6]
Automobile repair and services	.00114	.00522	CPI auto repairs [5]
Transferred imports	.07159	.00000	[1]
Business travel, entertainment and gifts	.00576	.00000	[3]
Scrap used and second-hand goods	.00573	.00000	[3]
II. CAPITAL EXPENDITURES			
Maintenance and repair construction	.03168	.14520	GNP deflator for fixed investment in oil and gas wells [7]
Cement, hydraulic	.0014	.00642	Price index for SIC 3241 - cement, hydraulic [2]
Blast furnace and basic steel products	.00796	.03648	Price index for SIC 3312 - blast furnace and steel mills [2]
Fabricated plate work	.0029	.01329	WPI metal tanks [2]
Pipe, valves and pipe fittings	.00351	.01609	Price index for SIC 3498 fabricated pipes [2]
Internal combustion engines	.00323	.01480	Price index for SIC 3519 internal combustion engines [2]
Construction machinery	.0009	.00412	WPI construction machinery and equipment [2]
Oil field industry	.0029	.01329	Price index for SIC 3533 oil field machinery and equipment [2]
Pumps and compressors	.0047	.02154	WPI pumps, compressors and equipment [2]
Power transmission equipment	.00059	.00270	WPI mechanical power transmission equipment [2]
Switch gear and switchboard apparatus	.00216	.00000	[3]
Motors and generators	.00552	.02530	WPI motors, generators, motor generators [2]
Industrial controls	.00101	.00463	WPI industrial controls [2]
Welding apparatus	.00131	.00000	[3]
III. LABOR COSTS			
Production, development and exploration workers	.03753	.17200	Average hourly earnings - crude oil production workers [8]
Other payroll	.05189	.23780	Average weekly earnings - professional and technical workers [6]
Supplemental labor costs	.00743	.03405	[9]
IV. REAL ESTATE COSTS	.16161	.00000	[1]
V. REMAINING VALUE ADDED	.48495		

REFERENCES FOR TABLE A-3

[1] Eliminated from index for reasons discussed in text.

[2] Wholesale Prices and Price Indexes, BLS: various issues.

[3] Eliminated from index because price index was not available or was available only for a small portion of the period 1965-1976.

[4] Transport Economics, ICC: various issues. Quarterly data interpolated from annual values except for railroads where a price index for railroad freight (BLS) was used from 1970 on.

[5] Consumer Price Index, BLS: various issues.

[6] National Survey of Professional, Administrative, Technical and Clerical Pay, BLS: various years. Weighted average of salaries of accountants, engineers and engineering technicians. Quarterly data interpolated from annual values.

[7] Unpublished Commerce Department data. Quarterly data interpolated from annual values.

[8] Employment and Earnings, BLS: various issues.

[9] Supplement as a percentage of wages and salaries multiplied by average hourly earnings - crude oil production workers. Supplements are the national average from National Income and Product Accounts, Dept. of Commerce.

TABLE A-4

WEIGHTS AND PRICE INDICES USED FOR THE COST INDEX AS CALCULATED FROM INDUSTRY DATA

	1974 Weight in Total Expenditure	Weight in Cost Index	Price Index
I. EXPLORATION			
Drilling and equipping exploration wells	.0585	.13946	JAS cost per foot of drilling and equipping wells [1]
Acquiring undeveloped acreage	.201	.00000	[2]
Lease rentals	.00661	.01576	JAS expenditures deflated by index of production [3]
Geological and geophysical	.02273	.05419	JAS expenditures deflated by crew months of geophysical activity [3]
Contribution toward test wells	.00121	.00288	JAS expenditures deflated by crew months of geophysical activity [3]
Land department - leasing and scouting	.00416	.00992	JAS expenditures deflated by crew months of geophysical activity [3]
Other - incl direct overhead	.0082	.01955	JAS total overhead expenditures deflated by total employment [3]
G&A overhead allocated to exploration	.01375	.03278	JAS total overhead expenditures deflated by total employment [3]
II. DEVELOPMENT			
Drilling and equipping development wells	.09540	.22742	JAS cost per foot of drilling and equipping wells [1]
Lease equipment	.02735	.06520	WPI oilfield machinery and equipment [4]
Improved recovery programs	.01417	.03378	JAS expenditures deflated by index of production [3]
Other - incl. direct overhead	.01240	.02956	JAS total overhead expenditures deflated by total employment [3]
G&A overhead allocated to development	.00966	.02302	JAS total overhead expenditures deflated by total employment [3]
III. PRODUCTION			
Production expenditures and direct overhead	.1246	.29703	JAS expenditures deflated by index of production [3]
Production of severance taxes	.04294	.00000	[5]
Ad Valorem taxes	.01364	.00000	[5]
G&A overhead allocated to production	.02074	.04944	JAS total overhead expenditures deflated by total employment [3]
IV. REMAINING VALUE ADDED	.32294		

REFERENCES FOR TABLE A-4

[1] Joint Association Survey of the U.S. Oil and Gas Producing Industry: various issues.

[2] Eliminated from index for reason given in text.

[3] Expenditures come from Joint Association Summary of the U.S. Producing Industry: various years. Crew month of geophysical activity comes from Geophysics: various issues. Index of crude oil production comes from Twentieth Century Petroleum Statistics, DeGolyer and MacNaughton. Total employment comes from Employment and Earnings: various issues.

[4] Wholesale Prices and Price Indexes: various issues.

[5] Eliminated to make index comparable with government sources.

APPENDIX B

THE ADJUSTED COST INDEX

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THE ADJUSTED COST INDEX

The cost index described in the text ignored several factors affecting the decision of how actively to search for new oil. In this appendix, we discuss the basic assumptions and the algebraic derivation of the cost index that takes these factors into account. First, we recognize that there is a time lag between outlays to discover new oil and receipts from selling it. This means that decisions must be based on expected future prices. Second, tax treatment of revenue might be expected to affect exploration incentives.

To derive a cost index incorporating these two points, it is necessary to use a specific model of how investors make decisions about exploration. The model described briefly in the following section is not intended to be a complete description of the decision process. It focuses only on the relation between the returns to exploration and input prices, one of several elements of cost. After presenting the model, the adjusted cost index is derived and calculated.

THE MODEL OF EXPLORATION

To describe our model of investor behavior, we use the case of an investor making a decision in 1970 as a specific example. This investor bases his decision about whether to undertake a given unit of investment on the expected net present value of his investment, using 10% as a discount rate. If the present value of expected receipts exceeds the present value of expected costs, i.e., if the expected return on the investment exceeds 10%, the investment will be undertaken.

In making this present value calculation, investors take into account the probability of finding oil. We desire to measure only the effect of input price changes instead of measuring also the effect of factor productivity changes. Hence, we apply the model as if the probability of finding oil and the size of the expected discovery do not change from year to year. We use this assumption even though each has, in fact, changed over time.

Since the 1970 investor bases his decision on expected receipts and costs, he must make some assumption about future input and output prices. We assume that expectations about future prices are based on current prices. In particular, we assume that the investor expects future input prices after 1970 to be equal to 1970 input prices, plus an 8% expected annual growth. We assume that output prices also are expected to rise at 8% per year from their 1970 level. Note that the model does not allow for historical experience to play a role in inflationary expectations.

Assuming an 8% rate of inflation and a 10% rate of return implies a very modest real rate of return of 2%. The model is slightly more general than it appears since any other combination of inflation and rate of return that yields a 2% real rate of return leads to the same result.

In addition to projecting input and output prices, the investor must also project tax treatment. We assume that he expects the 1970 tax treatment to persist for the life of his investment.

Investors calculate the present value of revenue and cost for different possible units of investment, and undertake those for which the present value of expected receipts exceeds the present value of current and expected costs. This process continues until the marginal unit of investment is reached, the unit for which expected revenue barely covers cost plus the 10% return on capital.

Clearly, the model is built upon the responsiveness of supply to expected price. We are assuming that if the current oil price (and hence expected prices) had been higher than the amount necessary to bring forth the specified level of finding, the finding rate would be greater. What had been the marginal unit of investment would no longer be marginal, but would yield a present value of expected revenue greater than the present value of expected costs.

Let us suppose that some investor in 1970 has invested in the marginal unit of investment. His profits over the long run will depend on how well he predicted how costs and prices would change in the future. If costs rose by 12%, rather than by the expected 8%, and prices rose by only the predicted 8%, he would undoubtedly lose money on his investments in exploration.

But now consider the marginal unit of investment for 1971. We assume the 1971 investor makes his calculations in the same way as the 1970 investor. He uses a 10% rate of return to calculate the present value of revenues and costs. He expects input prices and output prices to increase at 8% per year. But, of course, he bases his expectations on 1971 levels of cost and price, not 1970 levels. The 1971 investor will undertake the marginal unit of investment only if expected future prices (based on the 1971 price) will cover expected costs. Our price index will also have to rise between 1970 and 1971, by the ratio of 1971 costs to 1970 costs.

Suppose that between 1970 and 1971 each input had in fact increased in price by 12%, rather than by the 8% expected by the 1970 investor. The new investor in 1971 would still discount the expected future cost stream on the assumption that costs and revenues would rise by 8%. But since each current and expected input price in 1971 is 12% above the 1970 level, the price required to motivate the marginal unit of investment in 1971 will be 12% above the level in 1970.

ALGEBRAIC DERIVATION OF THE ADJUSTED COST INDEX

We described above a marginal unit of investment, as one for which the present value of costs and returns are equal. To derive our cost index, we begin with equation B-1 stating that the present value of receipts net of costs is 0. This equation is solved for the price of output and the price converted to an index. This index is the adjusted index of cost, where cost includes a 10% return on capital.

$$PV_t = \sum_{j=t}^{t+\ell} [R_j - C_j - T_j] [1+r]^{-(j-t)} = 0 \qquad \text{(B-1)}$$

where

PV_t is the discounted present value of expected net receipts in year t, when the discovery process begins

j is the year when receipts or costs accrue

ℓ is the lifetime of revenue from the discovery measured from the initial year of exploration

R_j is revenue expected in year j

C_j is expected cost in year j

T_j is tax expected in year j

r is the rate used for discounting to form a present value. We assume that this rate is 10%, the same for investments initiated in different years (t).

We now rewrite this equation in terms of the expected price of output in various years and the expected price of individual inputs. Several intermediate steps are helpful. First, expected revenue in year j is defined as the product of expected price (p_j) and expected quantity of oil produced (q_j).

$$R_j = p_j q_j \qquad \text{(B-2)}$$

Second, expected costs in year j is the sum of expenditures across individual inputs.

$$C_j = \sum_{i=0}^{I} w_{ij} x_{ij} \qquad \text{(B-3)}$$

where

C_j is cost expected in year j

i is the subscript for an individual input

I is the number of inputs less 1

w_{ij} is the price expected for input i in year j

x_{ij} is the quantity expected to be purchased of input i in year j.

Third, the taxation term (T_j) is expressed in terms of input and output prices. Taxes are the sum of state or local taxes and corporate income taxes. We define z_t to be state and local taxes as a fraction of revenue and we assume that this fraction is expected to remain constant throughout the lifetime of revenue from the investment. Hence, its only subscript is t, the year when the investment is first made.

The corporate income tax is expressed as the marginal tax rate, τ, multiplied by the base. For our index we use a constant rate of 48%. Hence, τ does not have a time subscript. This tax rate is applied to the base of the corporate income tax: revenue, minus state and local taxes, minus the depletion allowance, and minus depreciable costs. Multiplying the rate times the base, state, local, and federal taxes can be written in terms of input and output prices:

$$T_j = z_t p_j q_j + \tau (p_j q_j - d_t p_j q_j - z_t p_j q_j - \sum_{i=0}^{I} k_{it} w_{ij} x_{ij}) \qquad \text{(B-4)}$$

where

T_j is taxes expected in year j

z_t is the state and local tax rate on oil revenue

p_j is price expected in year j

q_j is expected output in year j

τ is the corporate tax rate

d_t is the fraction of revenue which can be excluded from the tax base under the depletion allowance

k_{it} is the fraction of expenditures on input i which can be excluded from the tax base as depreciation. Since allowable depreciation of a given expenditure is spread over future years, k_{it} is defined as the present value of this future depreciation divided by the amount of expenditure.

w_{ij} is the price of input i expected in year j

x_{ij} is the quantity of input i expected to be purchased in year j.

Expressions B-2, B-3, and B-4, above describe revenues, costs and taxes in terms of input and output prices. These are combined to rewrite equation B-1, in terms of input and output prices. Thus, the expression describing the net present value of the marginal unit of investment becomes as follows:

$$PV_t = \sum_{j=t}^{t+\ell} [p_j q_j - (\sum_{i=0}^{I} w_{ij} x_{ij}) - z_t p_j q_j - \tau (p_j q_j - d_t p_j q_j - z_t p_j q_j - \sum_{i=0}^{I} k_{it} w_{ij} x_{ij})] [1+r]^{-(j-t)} = 0 \qquad \text{(B-5)}$$

Rearranging terms yields the following:

$$PV_t = \sum_{j=t}^{t+\ell} [m_t p_j q_j - \sum_{i=0}^{I} n_{it} w_{ij} x_{ij}] [1+r]^{-(j-t)} \qquad \text{(B-6)}$$

where

$$m_t = 1 - z_t - \tau (1 - d_t - z_t)$$

$$n_{it} = 1 - \tau k_{it}$$

At this point, expression (B-6) does not specify a current price for crude oil, but a vector of future prices. To relate expected future and present prices requires an assumption about how expectations are formed. We assume that expected future prices are formed by inflating current prices at some rate h. Thus, we assume that

$$p_j = p_t (1+h)^{j-t} \qquad j > t \qquad \text{(B-7)}$$

We also make several further simplifying assumptions. We assume that each input cost is expected to rise at rate s.

$$w_{ij} = w_{it} (1+s)^{j-t} \qquad j > t \qquad \text{(B-8)}$$

Since we are assuming unchanged input productivity, we work with a fixed bundle of inputs. This means that the quantity of each input used a given number of years after initial exploration remains unchanged from one vintage to the next.

We can then represent the quantity of input i used in time j , in terms of quantity used in the base period and the fraction used a given number of years after exploration.

$$x_{ij} = x_{ib} f_{i\,(j-t)} \tag{B-9}$$

where

x_{it} is the quantity of input i used in period t

x_{ib} is the quantity of input i used to form the unadjusted indices.

$f_{i\,(j-t)}$ is the proportion of total use of an input that takes place (j-t) years after initial exploration.

Similarly, we assume that regardless of vintage, the same amount of production is expected a given number of years after initial investment. Thus, production (q) has subscript j-t.

Under the above assumptions, (B-6) simplifies to:

$$\sum_{j=t}^{t+\ell} p_t q_{j-t} \left[(1+h)/(1+r)\right]^{j-t} m_t$$

$$= \sum_{j=t}^{t+\ell} \sum_{i=0}^{I} w_{ij} x_{ib} f_{i\,(j-t)} \left[(1+s)/(1+r)\right]^{j-t} n_{it} \tag{B-10}$$

Solving for p_t yields

$$p_t = \frac{\sum_{i=0}^{I} w_{it} x_{ib} \sum_{j=t}^{t+\ell} f_{i\,(j-t)} \left[(1+s)/(1+r)\right]^{j-t} n_{it}}{m_t \sum_{j=t}^{t+\ell} q_{j-t} \left[(1+h)/(1+r)\right]^{j-t}} \tag{B-11}$$

We have assumed that q_{j-t}, r, and h do not vary between vintages of oil discovered in different years. These assumptions imply that the denominator in (B-11), except for m_t, remains unchanged for different vintages of oil. Hence the denominator will cancel out in forming an index, except for m_t.

The index, with base year b, takes the following form:

$$I_t = \frac{p_t}{p_b} = \frac{\sum_{i=0}^{I} w_{it} x_{ib} \sum_{j=t}^{t+\ell} f_{i(j-t)} \left[(1+s)/(1+r)\right]^{j-t} n_{it}}{\sum_{i=0}^{I} w_{ib} x_{ib} \sum_{j=b}^{b+\ell} f_{i(j-b)} \left[(1+s)/(1+r)\right]^{j-b} n_{ib}} \left(\frac{m_b}{m_t}\right) \qquad \text{(B-12)}$$

Multiplying and dividing the numerator by w_{ib}, and rearranging terms yields the final form of the index.

$$I_t = \frac{\sum_{i=0}^{I} V_i I_{it}}{I_{mt}} \qquad \text{(B-13)}$$

where

$$I_t = p_t/p_b$$

$$I_{mt} = \frac{m_t}{m_b}$$

$$I_{it} = \frac{w_{it}}{w_{ib}}$$

$$V_i = \frac{x_{ib} w_{ib} \sum_{j=t}^{t+\ell} f_{i(j-t)} \left[(1+s)/(1+r)\right]^{j-t} n_{it}}{\sum_{i=0}^{I} w_{ib} x_{ib} \sum_{j=b}^{b+\ell} f_{i(j-b)} \left[(1+s)/(1+r)\right]^{j-b} n_{ib}}$$

From (B-13) it is clear that the adjusted cost index is simply a weighted average of price indices for individual inputs (I_{it}) with an adjustment for tax treatment of revenue (I_{mt}). The weights (V_i) are equal to the share of each input in the present value of total input expenditures, where the present value is adjusted for tax writeoffs. Note that the adjusted index does not change the list of inputs used to calculate the cost index, but changes only the weights.

THE ADJUSTED COST INDEX BASED ON GOVERNMENT DATA

Two examples of the adjusted cost index were constructed, one based on government data, the other on industry data. The index based on government data is calculated annually from 1965 to 1969, then quarterly from 1970-I to 1976-II. In figure B-1 and table B-1, we compare the adjusted cost index with two other indices, the GNP deflator and the (unadjusted) cost index based on government data.

The adjusted cost index moves similarly to the unadjusted one, except at times when tax treatment of crude petroleum revenue became sharply less favorable. These times are 1969, when the percentage depletion allowance was reduced and 1975, when it was eliminated for the largest firms. During the seventies, both the adjusted cost index and the unadjusted cost index increase more rapidly than the GNP deflator.

THE ADJUSTED COST INDEX BASED ON INDUSTRY DATA

To further check our results, the adjusted index was recalculated using the industry data discussed in the text. In figure B-2 and table B-2 below, the adjusted index constructed from industry data is compared with the unadjusted industry cost index, and the GNP deflator. The adjusted index and the unadjusted index move similarly, except in 1969, when the percentage depletion allowance was reduced. The 1975 change in treatment does not affect this index since the index is calculated only through 1974. Both the adjusted and unadjusted indices increase more rapidly than the GNP deflator during the 1970's.

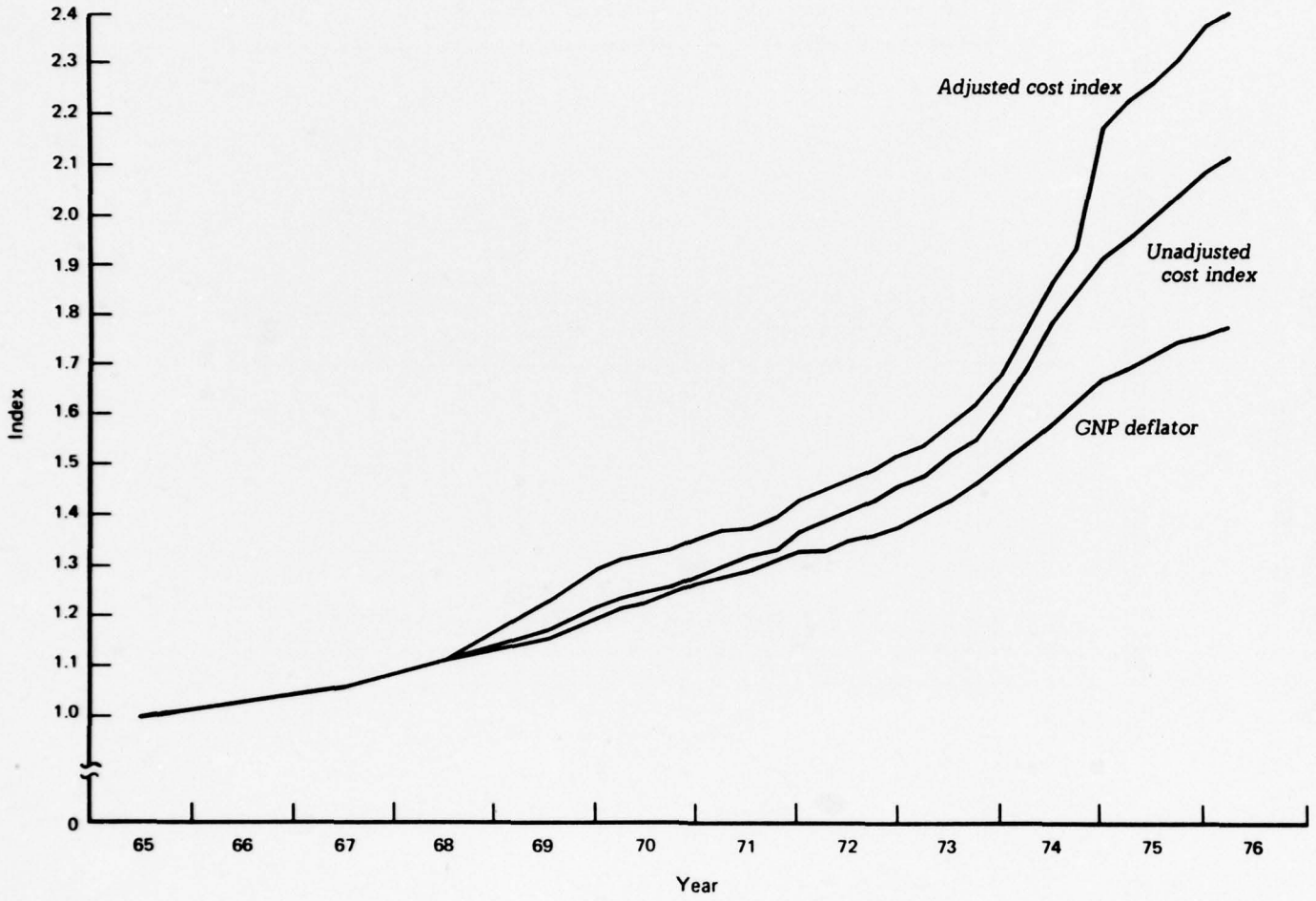

FIG. B-1: COMPARISON OF THE ADJUSTED AND UNADJUSTED COST INDICES BASED ON GOVERNMENT DATA AND THE GNP DEFLATOR: 1965-1976

TABLE B-1

A COMPARISON OF THE ADJUSTED COST INDEX
BASED ON GOVERNMENT DATA, THE
UNADJUSTED COST INDEX BASED
ON GOVERNMENT DATA AND THE
GNP DEFLATOR

Year or Quarter	Adjusted Index	Unadjusted Index	GNP Deflator
1965	1	1	1
1966	1.034	1.034	1.034
1967	1.069	1.066	1.063
1968	1.116	1.116	1.112
1969	1.230	1.175	1.167
1970-I	1.295	1.226	1.209
1970-II	1.310	1.241	1.223
1970-III	1.328	1.258	1.234
1970-IV	1.339	1.268	1.252
1971-I	1.359	1.288	1.271
1971-II	1.373	1.303	1.288
1971-III	1.378	1.322	1.299
1971-IV	1.395	1.338	1.311
1972-I	1.434	1.376	1.330
1972-II	1.456	1.397	1.339
1972-III	1.475	1.416	1.350
1972-IV	1.492	1.432	1.365
1973-I	1.523	1.463	1.385
1973-II	1.548	1.488	1.409
1973-III	1.582	1.520	1.435
1973-IV	1.620	1.554	1.468
1974-I	1.688	1.618	1.502
1974-II	1.771	1.696	1.542
1974-III	1.875	1.793	1.588
1974-IV	1.942	1.855	1.637
1975-I	2.189	1.925	1.677
1975-II	2.228	1.959	1.694
1975-III	2.277	2.002	1.724
1975-IV	2.320	2.040	1.754
1976-I	2.382	2.095	1.767
1976-II	2.411	2.121	1.787

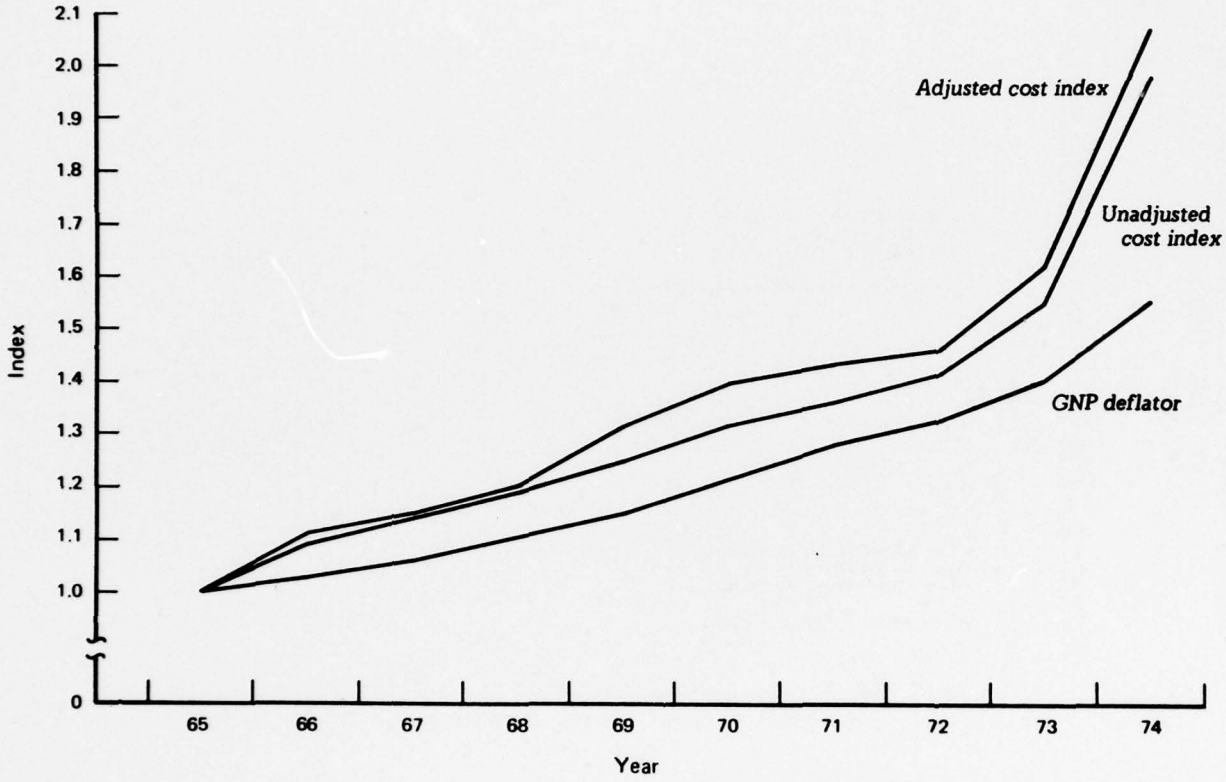

FIG. B-2: COMPARISON OF ADJUSTED AND UNADJUSTED COST INDICES BASED ON INDUSTRY DATA AND GNP DEFLATOR: 1965-1974

TABLE B-2

A COMPARISON OF THE ADJUSTED COST INDEX
BASED ON INDUSTRY DATA, THE UNADJUSTED
INDEX BASED ON INDUSTRY DATA, AND
THE GNP DEFLATOR

Year or Quarter	Adjusted Index	Unadjusted Index	GNP Deflator
1965	1	1	1
1966	1.101	1.098	1.034
1967	1.151	1.141	1.063
1968	1.206	1.198	1.112
1969	1.322	1.259	1.167
1970	1.406	1.321	1.229
1971	1.442	1.367	1.292
1972	1.479	1.426	1.346
1973	1.630	1.558	1.424
1974	2.083	1.989	1.567